Purdue University
Purdue e-Pubs

International Compressor Engineering Conference

School of Mechanical Engineering

1990

Diagnosis of Slides in Rotary Compressors Using Acoustic Emission Technique

K. Sato
Hitachi Ltd.

H. Hata
Hitachi Ltd.

T. Tanaka
Hitachi Ltd.

I. Sato
Hitachi Ltd.

T. Yoneyama
Hitachi Ltd.

DIAGONOSIS OF SLIDES IN ROTARY COMPRESSORS USING ACOUSTIC EMISSION TECHNIQUE

KOUICHI SATO,HIROAKI HATA,TOSHIYUKI TANAKA
Tochigi Works,Hitachi Ltd.

ICHIYA SATO,TAKAO YONEYAMA
Energy Reseach Laboratory,Hitachi Ltd.

ABSTRACT

This paper reports the analysis of rotating slides in rotary compressors for room air conditioners,using acoustic emission(AE) technique.

Firstly,AE characteristics in normal compressors without defects on sliding surface were investigated by AE monitering test. It was observed that a burst type AE signal generated,in synchronization with the each rotation. Investigation of the generating mechanism for normal AE signals showed that they are caused by batting phenomenon of a vane in vane-slot of cylinder. Next, in experimental test of compressors with artificial defects of rotating slides and in running test under the severe condition,burst and/or continuous type AE signals caused by defects and metal-contact among sliding parts were detected.

It was investigated through the tests that mean-to-peak ratio of AE signals indicates the condition of sliding parts of compressor. And We have applied the AE technique to diagnose rotating slide damage in rotary compressors.

INTRODUCTION

Recently,the quickness of cooling and/or heating after starting an air conditioner becomes one of the important ability. Therefore, of course,their rotating speed should be increased to more than the present speed to get large capacity. So it is very important to have more reliability of at high-speed rotating.

Reliability of rotary compressors has been evaluated through visual inspection by taking them apart after a long term running test. If techniques are made available which allow inspection without taking them apart,inspection efficiency will be improved and development of new products would be promoted.

We applied Acoustic Emission(AE)technique,which has been applied to machine condition diagnoses in large rotating machinery such us steam turbines and rolling mills,to diagnose the damage of rotating slides in rotary compressors.

STRUCTURE OF COMPRESSOR

Figure 1 shows the structure of a rotary compressor for room air conditioners. The rotary compressor consists of a crank shaft,a roller, and a vane.The crank shaft is supported by an upper bearing and a lower bearing ,and it is rotated by a moter. The crank shaft and the roller move in a rolling piston motion. Then the vane slides on the rotating roller with recyprocatingly moving in vane-slot of the cylinder.

If sliding damage is generated at the rotating slide portions above, the compressor will experience a drop in operating efficiency,as well as abnormal stops during operation.Therefore early detection of sliding damage is important for improved reliability.

AE BEHAVIOR UNDER NORMAL CONDITIONS

Acoustic emission behavior under normal conditions was observed with an AE sensor which was mounted on the chamber of compressors. Figure 2 shows a typical AE waveform under normal operation. As can be seen from this figure,a burst type AE signals(normal AE) is generated in synchronization with a rotation. And the normal AE signal is generated at the each top dead center.

Measured data of the AE source location using two AE sensors are shown in Figure 3. An AE senser S1 was mounted in the vicinity of the vane (top dead center),and an AE sensor S2 was mounted on the opposite side(bottom dead center). Test results showed that the AE signal reached to sensor S2 about 22μs later than to sensor S1.From the results described above,it seemed that the normal AE is generated from the vicinity of the Vane.

In order to confirm the normal AE source,artificial AE signals were generated from the vane. The result obtained for the artificial AE source location were almost the same as those of the normal AE source location as shown in Figure3. From these experimental results,We presumed that the generating mechanism for the normal AE is caused by batting phenomenon of the vane at the top dead center,as shown in Figure 4.

EVALUATION FOR TRIBOLOGICAL CONDITION USING AE TECHNIQUE

Next experiments were conducted to investigate the relation between AE patterns and triborogical condition of journal bearings. Oil film thickness can be maintained between crank shaft and bearings in normal condition. But high load and low vicosity of oil caused metallic contact of bearings because of decrease of oil film thickness. It is estimated that the metallic contact generated AE signals in such a case. Therfore tribological conditions of sliding surfaces can be evaluated by monitoring AE patterns detected from compressor.

The AE patterns and luburicant conditions were investigated with test compressor in Figure 6. And Figure 7 shows the relation between AE signals and lubrication condition when the heat pump started after being stopped through the night at low temperature(-10℃).

The following AE parameters were used to evaluate the lubricant condition. Kmp,the mean-to-peak ratio,is obtained with the following equation:

$$Kmp = Vm \;/\; Vp \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where Vm is the mean value and Vp is the highest peak value of AE signals. Rmc,the percentage of metallic contact at journal bearing,is obtained by the following equation:

$$Rmc=(\text{Sum of hatching area in Figure 5 /Area of squareABCD}) \times 100 \cdot\cdot (2)$$

In Figure 7,AE parameter Vmp was changing relative to percentage of metallic contact Rmc. From this test results,we had possibility to evaluate the lubricant condition of compressors without disassemble using AE technique.

AE BEHAVIOR OF COMPRESSORS WITH DEFECTS

In order to investigate AE patterns of compressors with defects, experiments were conducted using compressors with artificial defects. Figure 8 shows examples of compressors with artificial defects and their AE waveforms. The artificial defects to imitate abrasion damage were made by a punch and those to imitate wear damage were made with sandpaper. AE patterns of the compressors with defects have the following characteristics.

(1) AE characteristics of compressors with abrasion damage include a number of burst type signals which are generated among low level normal AE signals.

(2) AE characteristics of compressors with wear damage are the continuous type signal in synchronization with a rotation.

In order to confirm the relation between AE signals and damage in sliding surfaces, high load test was performed using compressor with oil half amount less than usual use and with 1.5 times more refrigerant. The inspections of sliding surfaces of parts in compressor were done when abnormal AE signals were detected after on/off running test. Figure 9 shows the relation between AE waveforms and roughness of sliding surfaces.

This test indicated that damage whose roughness was over 6 μm generated a number of burst type AE signals. Therefore, we can find the defects whose roughness of sliding surfaces is over 6 μm by using AE technique without disassemble.

CONCLUSIONS

A diagnostic system using AE technique was developed for nondestructive monitoring of the rotating slides of compressors for air conditioners. AE characteristics of rotary compressors are summarized as follows:

(1) Typical AE patterns under normal conditions are burst type AE (normal AE), which is caused by butting phenomenon of the vane, in synchronization with the rotation.

(2) AE technique based on mean-to-peak ratio of the signal is useful for monitoring lubricant condition in compressor.

(3) AE characteristics of compressors with abrasion damage include a number of burst type signals, and compressors with wear damage give continuous type signals. Damage with roughness over 6 μm can be found nondestructively by monitoring AE signals .

REFERENCES

1. I.Sato, et al., "Machine Condition Diagnosis System Using Acoustic Emission Techniques", Proceedings of the 8th International Acoustic Emission Symposium, Tokyo, 65-72(1986).
2. I.Sato, et al., "Diagnossis of Rotating Slides in Rotary Compressors using Acoustic Emission Technique, Journal of Acoustic Emission, Vol.7, No.4, 1988.
3. H.Hata, et al., "Evaluation of AE Behavior and Tribological Condition for Rotary Compressor using Acoustic Emission Technique", REFRIGERATION(Japanese Association of Refrigeration), Vol.65, No.748 (1990)

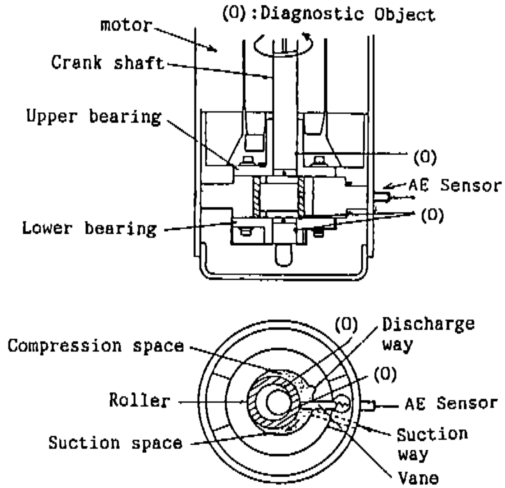


Fig.1 Structure of rotary compressor

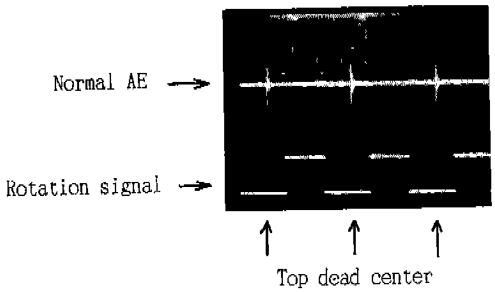


Fig.2 Typical AE signals under normal operation

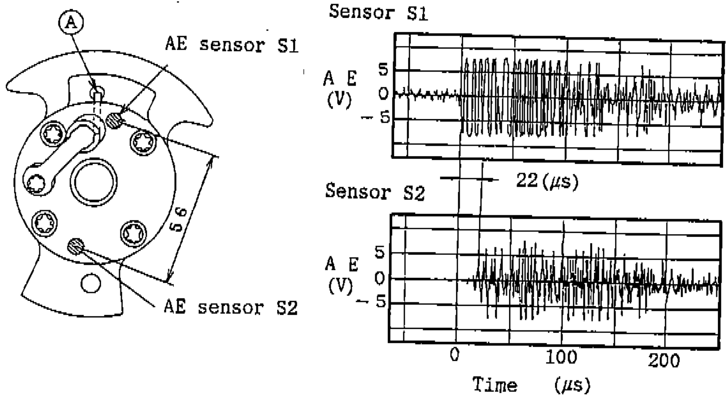
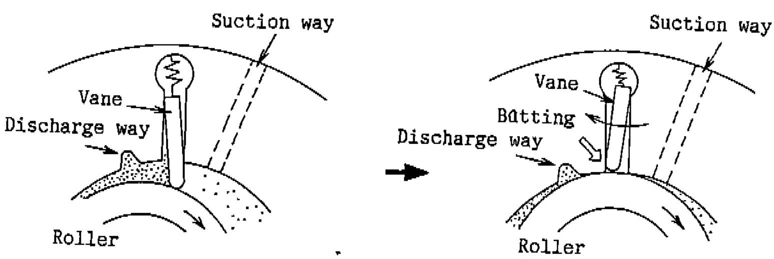


Fig.3 The AE source location using two AE sensors on a test compressor



(a) Vane is pushed to a wall plane of Suction side

(b) Vane butts a wall plane of discharge side

Fig.4 The mechanism of normal AE generation

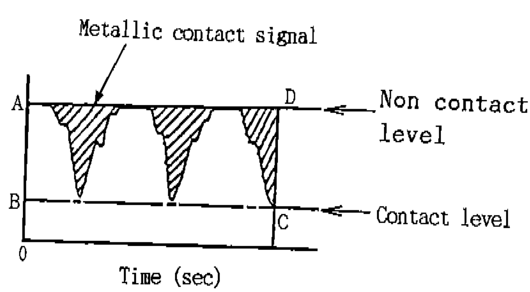


Fig.5 Estimation of metallic contact at journal bearing

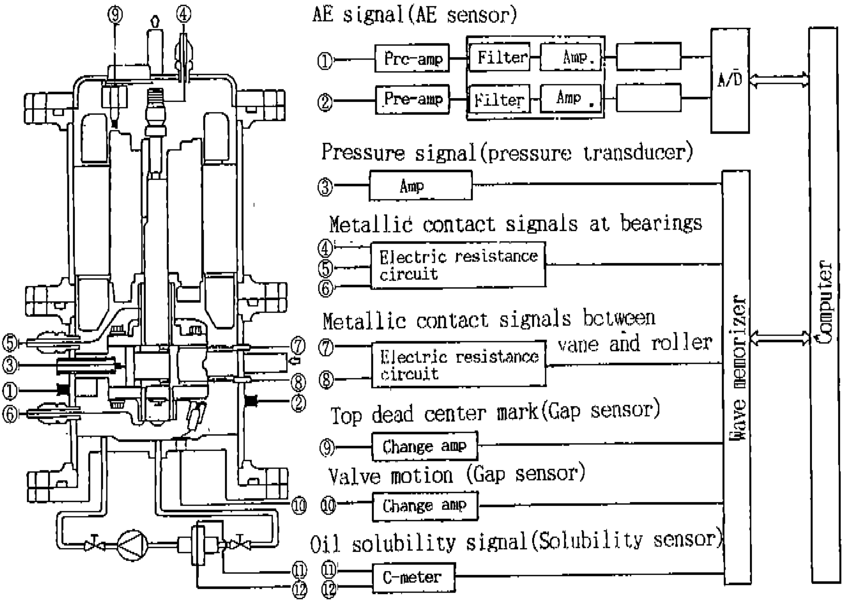


Fig.6 Sectional view of test compressor

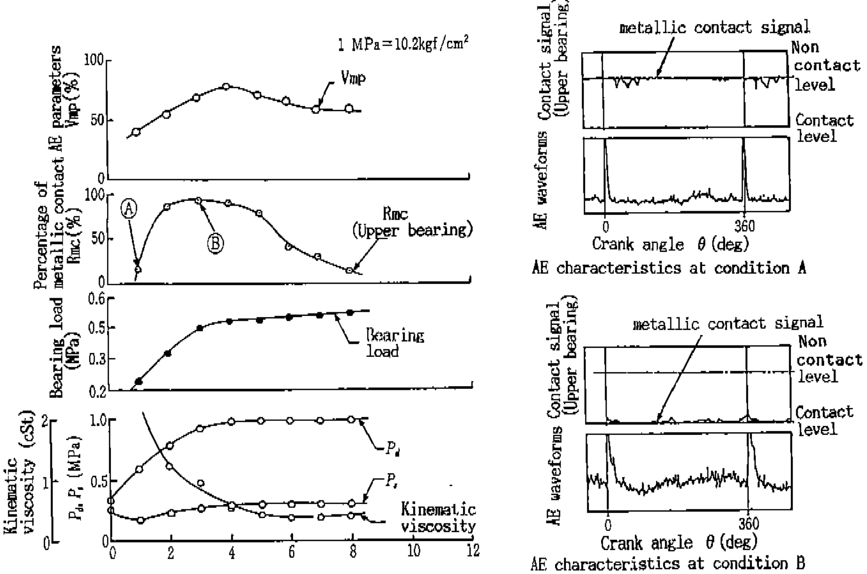


Fig.7 Lubricant condition and AE characteristics at cold start

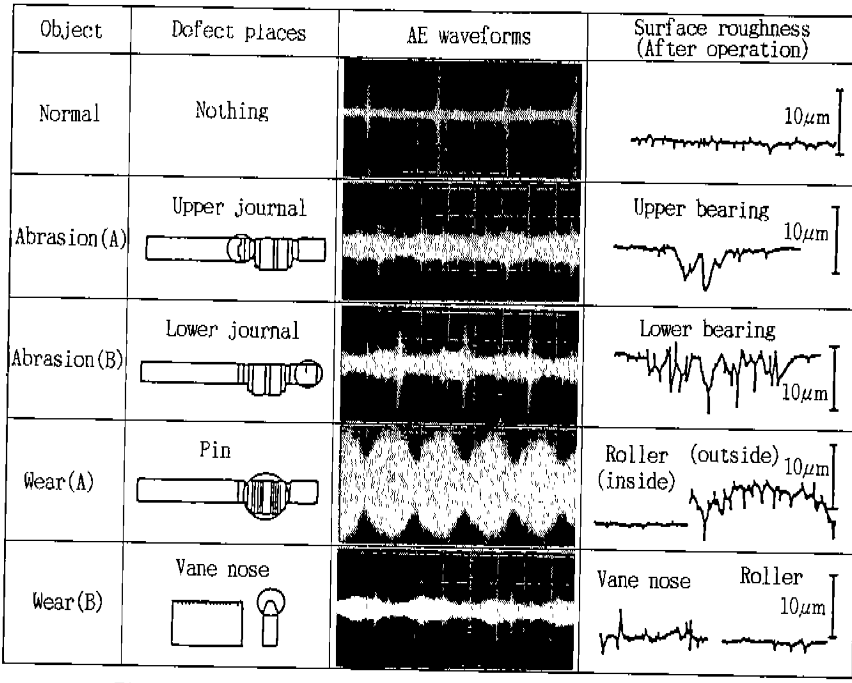
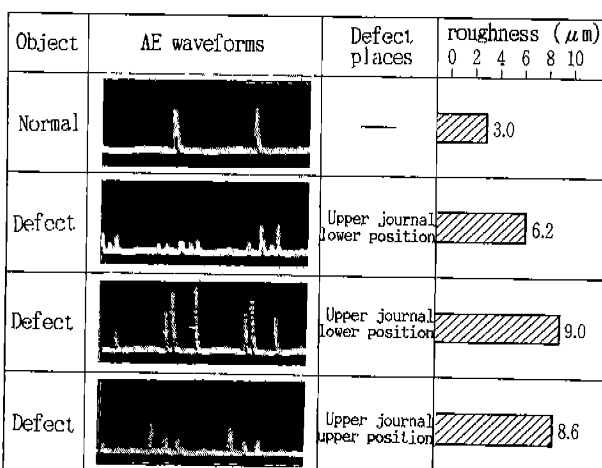


Fig.8 Examples of compressors with artificial defects and their AE waveforms



(Rotation speed:3000rpm,Ps/Pd = 0.54 MPa / 3.33 MPa)

Fig.9 The relation between AE waveforms and roughness of sliding surfaces